A BIOLOGICAL NOTE ON THE SIZE OF EVERGREEN NEEDLES.

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THE profound influence which a prevalence of favorable or unfavorable weather in any season exerts upon the growth of stems is a matter of universal observation. Inadequate nutrition of the plant may be expected, and in general will be found to find expression in a more or less stunted development of both internodes and leaves; though in individual cases this parallel influence may be concealed by the different response of the two members to variations in light or moisture, acting as stimuli.

The best specific instance, with which I am acquainted in literature, of the effect of imperfect nutrition upon the growth of leaves, is in a brief note by Reinke,[1] who measured, on young trees of a number of species of Pinus and Abies, the length of needles formed (*a*) the year before the trees were transplanted, (*b*) the year when they were transplanted, and (*c*) the second year thereafter. In consequence of injury to the roots during transplanting, the needles formed during that year were materially shorter than those of preceding or following seasons.

Gregor Kraus[2] observed that the length of the needles varies from year to year[3] under the influence of "Boden und Klima," and mentions several instances: as one, in which the size of the leaves of deciduous trees is affected by the different illumination of different parts of the tree; and another in which,

[1] Berichte d. d. bot. Gesells. **2**: 376.

[2] Abhandl. d. naturf. Gesells. zu Halle **16**: 363. 1886.

[3] *Ibid.* 365. "Die absolute Länge der Nadeln eines Triebes hängt mit der Kräftigkeit des Jahrestriebes überhaupt zusammen. In günstigen Jahren werden bekanntlich sehr lange und kräftige, in ungünstigen viel kleinere und schwächere Triebe gebildet, und die Kräftigkeit oder Schwächlichkeit gilt nicht bloss für die Achsen, sondern auch für die Blätter."

the strength of the tree going largely to the fruit, fruiting apple trees bore smaller leaves than sterile ones. From a prevalent occurrence of shorter needles on the youngest year's growth, and from direct measurements, Kraus advanced the doctrine of a further growth in length of the needles of Pinus after the first year; which Meissner[4] and S. Honda,[5] from a mass of negative results deny. From his numerous measurements Meissner recognized the variations from year to year, and seems to regard this observation as one of his most important results.[6] But though he mentions in one place (*ibid.* 217, 1897) the effect of a dry summer in the growth of short needles, he introduces without explanation the fact that the variations on the main stem and on its branches are parallel, and expressly contradicts Kraus' statement that there is a relation between the length of the stem and that of the needle. As illustrating and emphasizing the influence of the conditions of vegetation on the development of leaves, the following notes may be of interest, although their most conspicuous feature is that already chronicled by Reinke.

In the spring of 1896 a considerable number of evergreens were transplanted to the campus of Indiana University. The most of these are still living, and except in the case of *Pinus Strobus* still bear leaves three, four, or more years old. I have measured needles from two or more plants of each species and in the appended tables present a fair average case of each. In every instance the needles formed during 1896 are conspicuously shorter than those of 1895 or 1897, giving the young trees a very odd appearance. The per cent. of shortening varies of course in the different plants, according to the injury they sustained in being moved.[7] The greatest decrease present in the tables is 74.6 per cent. on *Pinus Austriaca*. A still greater effect

[4] Bot. Zeit. **52**[1]: 55. 1894, and **55**[1]: 203. 1897.

[5] Not seen. Ref. Bot. Centralb. **67**: 25.

[6] Loc. cit. 217. 1897. "Die Nadeln nehmen von Jahr zu Jahr an Länge zu, dann ab, dann wieder zu, etc."

[7] REINKE, loc. cit. *Abies brachyphylla*, transplanted without injury to the roots, showed no change in the needles.

was observed in many instances; in fact it not infrequently occurred that *no* leaves were formed during 1896, the apical bud having remained almost dormant through that year, and grown again normally in 1897. Since it was the weakness of the trees as a whole that found expression in the stunted needles, it was bound *a priori* to show itself alike on all stems and branches, of whatever order, and I have thought it worth while to show this only in table IV. It was equally to be expected that such profound variations in the strength of the plants would affect the stems and the leaves alike, and as all the tables show, this was found to be true. In some cases the effect was most marked in the leaves, in others, notably Taxus, in the stems.

The growth of the stem in thickness was likewise uniformly checked. Thus in all cases the annual ring formed in 1896 was appreciably thinner than that of other years; which indeed was to be expected, as merely an unusually dry season is able to leave its record in a thinner ring. The leaves formed in 1896 were not only shorter but less in diameter as well, as is shown by the area of their cross sections. The leaves measured were among the largest of each year's growth. The measurements were made by drawing the outlines with a camera lucida on paper of uniform thickness and cutting out and weighing the sketches.

On trees set out in 1897 (table VII) it was of course that year in which the needles were dwarfed in length and diameter, and the annual ring remained thin.

While the shorter stem-segments of the season following transplanting bore also shorter leaves, they were much more densely beset by them; so that in most of the tables the total number of needles formed is found to have been greatest in that year.[8] I forbear to offer any hypothetical explanation of this interesting phenomenon. The number of needles compensates the plant for their lack of size, sometimes furnishing an even

[8] MEISSNER sometimes confuses the internode with the year's growth in length. The internodes are much more conspicuously shortened after transplanting than is even the year's growth, since their number is commonly increased.

greater surface of leaf than is borne on the normal year's growth of stem.

As clearly noted by Kraus, and emphasized almost humorously by Meissner, the length of the needles formed during different years on *uninjured* trees varies considerably with the prevailing climatic conditions. This appears undisturbed only in table VIII, which is introduced rather to show what might have been expected during these years, of the smaller trees, if their development had not been interrupted. There is absolutely no reason for suspecting an automatic periodicity in the length of the needles. These constant yearly fluctuations can only be regarded as less conspicuous symptoms of the same general state of matters which when exaggerated finds expression in the various phases of dwarfing of transplanted trees. In the latter case, that of transplanted trees, if we seek to apply the old "law of the minimums" it is probably safe to say (overlooking the possibility that this is in part an instance of "correlation") that the inability to get a proper supply of water is the factor which places the limit on growth. This must often be true, too, when the variations depend on the "Klima;" and the summer of 1897 (see table VIII) was indeed a destructively dry one in Bloomington. But the early part of the same season was unusually cold, and what part of the failure of the needles to reach their average length was due to the drought, and what to the late spring, cannot be said. To analyze the complex of conditions comprehended under a season's "weather" is not immediately practicable.

Even in the relatively simple case of transplanted trees Reinke probably went astray when he attempted any further analysis of the cause of dwarfing. He satisfied himself, in some way, that enough water was absorbed through the periderm of the old roots to cover the loss by transpiration, and concluded therefore that the normal development of the leaves is in part dependent upon the root pressure. Very probably it does depend upon the amount of water present within the plant; but before one ascribes a share in it to actual root pressure, it should be shown that there is some pressure under normal conditions, present throughout the season of active growth; or that the length of the needles varies—as the root pressure probably does, if present at all—with the distance from the ground.

Since the variation from year to year, like the disturbances following transplanting, depends upon the general condition of the tree, it is self-evident that they will be the same on the main axis and on all its branches.

The most casual observation shows that in this climate the needles or leaves formed during any year are at first very short, afterward longer, and at the end of the season again short. In measuring the needles to find the average length for each year, it was immediately apparent that the progression in the length of the needles was surprisingly uniform. The first lines of figures in the individual tables show this almost as forcibly as plotting the curves would do. Each measurement is the average of ten successive needles, except in the instance of *Pinus Austriaca*, in which ten pairs of needles were taken. The figures at the beginning of each line represent the lowest needles on the year's growth of stem. Ten leaves taken each time is too many to show the curve in any detail when the year's growth bears as few leaves altogether as in the instances of Tsuga and Taxus; but on branches so conspicuously dorsiventral the leaves borne on the under side are so much longer than those above that taking a smaller number each time yields too broken a curve. The series of needles still clinging to stems more than three years old is usually quite incomplete, but except in one or two cases I have been unable to see that the shorter needles were cast off before the longer.[9]

The numbers representing the needle lengths advance each year from the spring minimum to a maximum, usually near the middle of the yearly growth in length, and then decrease to the fall minimum, which is usually lower than the first one. In many of the tables there is no break in the rise or fall, and what

[9] S. HONDA, loc. cit.: On species of Pinus he found the smallest leaves formed latest each year, and seldom clinging more than one year to the stem.

irregularities do appear in others are insignificant. The curves plotted from these data are at least as regular as can be obtained from actual measurement during the season. And while the causal connection of the two curves is not actually demonstrated, I do not doubt that both represent the same thing, the different vital activity at different seasons, as the plant gradually arouses from its winter rest in spring and sinks into it in late summer and fall. The tree keeps its own record of its annual period of activity in the length of its needles; and we do very well if the record we construct from continuous measurement of the rapidity of growth is equally legible.

The cause of this regular annual variation is the same complex, constituting its environment, which in some years stimulates the growth of longer, in others, of shorter leaves all summer; with perhaps a larger part played by the temperature, and less by the moisture, in the production of the rhythmic than of the irregular variations. How little the regular annual period depends upon present conditions, and how largely it is hereditary, in response to the climatic conditions of the plant's ancestors, cannot now be said, but it probably depends very much upon the species. No conclusions can be drawn from the Araucarias[10] in a local greenhouse, which show occasional zones of short leaves, corresponding possibly to periods of rest, for the greenhouse is only an attempt to reproduce their natural climate.

TABLES.

Except where otherwise specified, the measurements are made from lateral branches of the first order. In each table the average needle-length in successive zones, of ten needles each, from below upward, illustrating the regular yearly rise and fall in needle-length, is given first. Then follow the average *needle-length* of each year, the area of the *cross section* of a large needle, the length of the year's growth of *stem* (the same on

[10] DE BARY: Comp. Anat. 513. Annual rings are not always regularly present in the wood of Araucaria.

which the measured needles grew), and the thickness of the annual *rings*. The needles are measured in millimeters.

I. *Pinus Austriaca* Hors.

1895. 104.0, 106.4, 106.2, 104.2, 101.0 (11 pairs).

1896. 25.9, 27.7, 29.1, 29.6, 29.4, 28.5, 29.0, 29.1, 28.5, 28.3, 27.1, 25.2, 24.6, 23.9, 23.3, 23.1, 22.7, 22.2 (12 pairs).

1897. 107.1, 113.9, 112.8, 114.0, 114.0, 105.6 (12 pairs).

	Needle-length	Cross-section	Stem	Rings
1895.	104.36^{mm}	0.864$^{mm\ sq}$	22^{cm}	35 tracheides.
1896.	26.51	0.523	7.8	22 "
1897.	111.23	1.188	8.2	75 "

Though the response of the plant to its injury was more marked in this tree during 1896 than in any of the other trees represented by tables, its recovery by the next year was unusually complete, only the stem's growth in length seeming still to suffer.

II. *Pinus Strobus* L.

There were too few needles for their sequence to be instructive. In the growth of 1897 they were borne uniformly in fives; in that of 1896, often in threes or fours. Those of 1895 were all fallen.

	Needle-length	Cross section	Stem	Ring
1896.	59.57^{mm}	0.227$^{mm\ sq}$		0.189^{mm}
1897.	83.39	0.296		0.307

III. *Picea alba* Link. (*P. Canadensis* (Mill.) B. S. P.). Seven-year old tree.

1895. 9.0, 11.7, 13.9, 14.0, 14.8, 15.4, 15.5, 15.5, 15.4, 15.5, 15.1, 15.0, 14.4, 13.3, 12.3 (6 needles).

1896. 4.3, 5.1, 5.7, 6.2, 6.6, 7.1, 7.4, 7.8, 8.0, 8.0, 8.1, 8.4, 8.3, 8.3, 8.3, 8.2, 8.2, 8.0, 7.9, 7.7, 7.5, 7.4, 7.1, 6.8, 6.3, 5.7 (12 needles).

1897. 10.7, 13.5, 16.6, 17.6, 18.4, 19.5, 19.7, 20.2, 20.2, 20.4, 20.4, 20.3, 19.8, 19.6, 19.5, 19.1, 18.2, 17.8, 16.8, 14.9, 14.4, 12.6, 7.8.

	Needle-length	Cross section	Stem	Ring
1895.	14.05^{mm}	0.418$^{mm\ sq}$	15.3^{cm}	0.430^{mm}
1896.	7.25	0.262	6.7	0.185
1897.	17.30	0.600	14.0	0.298

IV. *Picea pungens* Engelm. About six years old.

1894. 13.9, 15.5, 15.6, 15.6, 15.8, 15.9, 15.4, 15.0, 14.8, 14.6, 14.3 (12 needles).

1895. 13.0, 15.1, 16.9, 17.0, 17.4, 17.5, 17.7, 17.4, 17.2, 17.1, 16.8, 16.5, 16.0, 15.6, 14.4, 12.9 (11 needles).

1896. 5.6, 7.5, 8.2, 8.5, 9.3, 9.7, 9.9, 10.0, 10.1, 10.2, 10.1, 10.3, 10.3, 10.4, 10.4, 10.5, 10.5, 10.0, 8.1 (7 needles).

1897. 11.7, 13.0, 13.9, 14.7, 15.0, 15.0, 14.9, 14.8, 14.7, 14.4, 13.8, 13.1, 12.4, 10.2.

	Needle-length	Cross section	Stem	Ring
1894.	15.13^{mm}		7.1^{cm}	
1895.	16.16	0.847$^{mm\ sq}$	8.2	0.262^{mm}
1896.	9.45	0.477	6.3	0.148
1897.	13.69	0.688	6.5	0.536

Branch of second order.

1895. 11.0, 12.9, 13.6, 14.0, 14.0, 14.3, 14.2, 14.1, 14.1, 13.6, 13.3, 13.0, 11.6 (14 needles).

1896. 4.7, 6.8, 7.9, 8.6, 8.5, 8.4, 7.6, 6.5, 4.9.

1897. 11.3, 12.6, 13.3, 13.8, 13.8, 13.7, 13.4, 13.1, 12.7, 11.9, 9.5 (8 needles).

	Needle-length	Stem
1895.	13.36^{mm}	6.2^{cm}
1896.	7.1	2.7
1897.	12.65	4.4

One year is not always sufficient for recovery from the injury of transplanting. Trees as young as these, if left to themselves, produce every year longer leaves than the year before. So the length in 1897 would naturally exceed that in 1895.

V. *Picea nigra* Link (*P. Mariana* (Mill.) B. S. P.).

1895. 7.7, 8.5, 9.6, 10.2, 10.7, 11.0, 11.4, 11.7, 11.9, 11.8, 11.8, 11.8, 11.8, 11.7, 11.5, 11.4, 11.1, 10.6, 10.4, 10.0.

1896. 3.4, 5.1, 6.3, 6.5, 6.8, 6.9, 7.0, 7.0, 7.0, 7.0, 7.1, 7.0, 7.1, 7.2, 7.0, 7.0.

1897. 7.6, 10.4, 11.5, 12.8, 13.3, 13.6, 13.6, 13.8, 13.7, 13.8, 13.8, 13.7, 13.7 13.4, 13.2, 12.9, 12.8, 12.6, 12.3, 12.2, 11.8, 8.4.

	Needle-length	Cross section	Stem
1895.	10.83^{mm}	0.415$^{mm\ sq}$	9.7^{cm}
1896.	6.59	0.222	4.3
1897.	12.50	0.409	8.1

The annual ring of 1896 was thinner than the others.

VI. *Picea excelsa* Link. Six-year old tree, transplanted in 1896.

1895. 14.4, 15.5, 16.1, 16.1, 16.5, 15.7, 16.1, 15.8, 15.8, 15.4, 15.6, 14.7, 14.3, 13.4, 13.2, 12.8 (12 needles).

1896. 8.2, 9.9, 10.9, 11.1, 11.3, 11.5, 11.6, 11.4, 11.3, 11.3, 11.2, 11.1, 11.0, 10.9, 10.7, 10.5, 10.5, 10.4, 10.0, 9.8 (11 needles).

1897. 15.8, 17.7, 19.3, 19.5, 19.7, 20.1, 20.1, 19.6, 19.7, 19.4, 18.8, 18.6, 15.8, 12.0, 10.6 (7 needles).

	Needle-length	Cross section	Stem	Ring
1895.	15.09^{mm}	$0.483^{mm\ sq}$	8.3^{cm}	0.325^{mm}
1896.	10.73	0.307	6.4	0.127
1897.	17.78	0.543	9.9	0.245

VII. *Picea excelsa* Link. Seven-year old tree, transplanted in 1897.

1895. 16.9, 19.1, 20.4, 21.5, 21.5, 21.2, 21.4, 21.4. 20.7, 19.1, 14.2 (5 needles).

1896. 12.8, 14.5, 15.8, 16.8, 16.9, 16.8, 16.8, 16.2, 15.6, 15.2, 14.6, 12.2 (14 needles).

1897. 6.2, 8.3, 9.0, 9.3, 9.6, 9.8, 9.8, 9.8, 9.6, 9.8, 9.6, 9.5, 9.5, 9.6, 9.1, 9.2, 8.9, 8.9, 8.7, 8.3, 8.0, 8.0, 7.8, 7.4, 6.7 (6 needles).

	Needle-length	Cross section	Stem	Ring
1895.	19.77^{mm}	$0.494^{mm\ sq}$	11.1^{cm}	0.300^{mm}
1896.	15.35	0.419	12.8	0.240
1897.	8.82	0.191	4.6	0.144

VIII. *Picea excelsa* Link. Tree about twenty-five years old. Lateral branch of second order.

1894. 16.5, 18.4, 19.6, 20.0, 20.3, 19.9, 20.4, 20.6, 21.0, 21.1, 20.8, 20.6, 19.6, 19.9, 18.5, 18.3, 17.9 (7 needles).

1895. 18.2, 21.8, 22.8, 22.4, 23.1, 24.0, 23.1, 23.1, 23.0, 21.7, 21.2, 19.7 (12 needles).

1896. 19.0, 20.1, 20.7, 21.1, 22.1, 22.3, 22.8, 22.3, 22.6, 22.2, 21.8, 21.8, 21.8, 21.1, 16.7 (13 needles).

1897. 15.5, 17.7, 18.6, 18.7, 18.6, 18.0, 18.2, 18.2, 18.0, 17.3, 17.6, 16.8, 16.0, 15.2, 15.2, 16.0, 12.9.

	Needle-length	Stem
1894.	19.61^{mm}	9.8^{cm}
1895.	22.01	10.0
1896.	21.23	10.2
1897.	16.97	11.0

IX. *Abies balsamea* (Linn.) Mill.

1895. 10.5, 13.1, 14.6, 16.2, 16.5, 15.9, 14.6, 13.9, 13.6, 12.3, 10.4.

1896. 6.5, 7.6, 8.5, 8.7, 9.0, 9.1, 9.2, 9.2, 8.9, 8.7, 8.9, 8.4, 8.1, 8.1, 7.5, 7.3, 6.8, 6.2, 5.7, 4.4 (8 leaves).

1897. 13.2, 15.6, 16.8, 17.2, 17.6, 16.8, 16.4, 15.7, 14.6, 14.0, 13.1, 9.5 (8 leaves).

	Needle-length	Cross section	Stem	Ring
1895.	13.78^{mm}	$0.307^{mm\ sq}$	10.9^{cm}	0.206^{mm}
1896.	7.84	0.354	4.4	0.07
1897.	15.04	0.477	6.3	0.115

X. *Tsuga Canadensis* (Linn.) Carr.

1896. 7.5, 8.1, 7.6, 7.3.

1897. 8.1, 9.2, 8.3, 8.1, 6.9, 5.9 (13 leaves).

	Leaf length	Stem
1895.	10.00^{mm}	9.2^{cm}
1896.	7.62	2.5
1897.	7.75	4.1

Many of the small dorsal leaves do not cling to the stem more than one year; hence the figures for 1895 and 1896 are too large in proportion to those for 1897.

XI. *Taxus baccata* L.

1895. 13.0, 16.9, 16.3, 12.7, 11.0, 9.9.

1896. 7.9, 8.4, 5.7 (6 leaves).

1897. 13.9, 17.2, 17.3, 14.9, 7.5 (4 leaves).

	Leaf length	Cross-section	Stem	Ring
1895.	13.3^{mm}	$1.318^{mm\ sq}$	8.3^{cm}	39 tracheids
1896.	7.58	0.773	2.1	6 "
1897.	15.07	1.045	8.2	20 "

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